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Publication date:
2017

Document Version
Peer reviewed version

Supported Alloy Nanoparticles Arrays with Highly Controlled Composition for Plasmonics

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Abstract: We present a generic nanofabrication method to produce supported, homogeneous alloy nanoparticles relevant for plasmonics with precise control over composition and dimension. We also demonstrate its application for a device as all-optical hydrogen sensors whose performance exceed the requirements for automotive industries.

Mixing metals at the nanoscale to obtain alloy nanostructures with tailored physicochemical properties offers appealing opportunities in catalysis and solid state devices. The precise control of the alloy dimension and composition in nanoparticles and the batch-to-batch reproducibility is often limited in colloidal synthesis methods, with a few exceptions [1]. Furthermore, integration to a (large) surface relevant for application in devices in a controlled mannered is extremely difficult if not impossible. To address this deficiency, we introduce a generic nanolithography-compatible strategy to fabricate arrays of supported alloy nanoparticles with fine-tuned composition [2]. Our approach is based on automated layer-by-layer physical vapor deposition of alloy constituents through a nanofabricated mask and subsequent annealing. We demonstrate the nanofabrication of large (cm^2) area arrays of nanoparticles of binary and ternary Au alloy with Ag, Cu and Pd. We characterize in detail the nanoparticles by electron microscopy and energy-dispersive X-ray spectroscopy and we find their composition to match the nominal one with excellent precision. Then, we characterize and discuss their plasmonic properties.

To demonstrate a specific application being enabled by our fabrication method, we present a plasmonic all-optical hydrogen sensing [3]. By mixing Au and Pd up to 25 at. % we were able to suppress the hysteresis during hydrogen uptake/release inherent for pure Pd system. Consequently we improve the accuracy to be below 5%. This advance is accompanied by higher sensitivity for low hydrogen pressure and sub-second response time; all parameters to exceed the hydrogen sensor requirements for automotive industries [4].

The possible combination of spectrally tunable plasmonic characteristics and tailored chemical properties for a specific targeted function promises to have a significant impact in applications such as plasmonic gas sensing, metamaterials and plasmon mediated catalysis, and we argue will open the door to the field of “alloy plasmonics”.

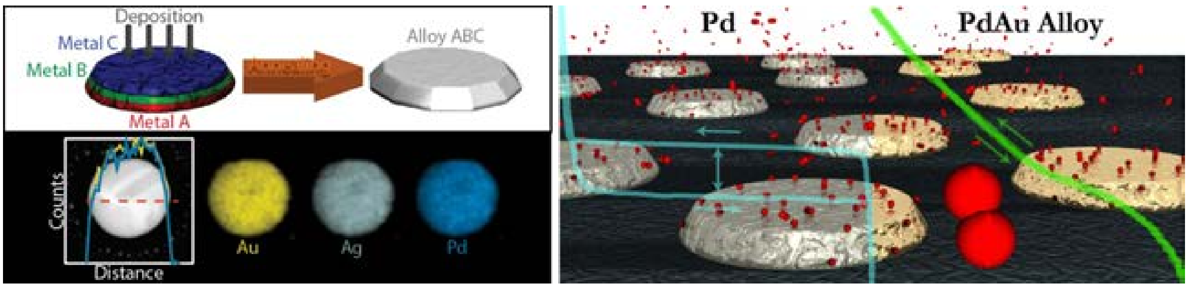

Fig. 1. (Left): Schematic of the fabrication strategy for alloy nanoparticles based on layer-by-layer evaporation and annealing. Shown below is an EDX analysis of AuAgPd ternary alloy nanoparticle exhibiting homogeneous alloy mixing. (Right): Conceptual schematic of AuPd alloy nanoparticles hydrogen sensor.

[1] A. –M. Dallaire, D. Rioux, A. Rachkov, S. Patskovsky, M. Meunier, *J. Phys. Chem. C* **116**, 11370–1137 (2012).
[2] F. A. A. Nugroho, B. Iandolo, J. B. Wagner, C. Langhammer, *ACS Nano.* **10**, 2871–2879 (2016).
[3] C. Wadell, F. A. A. Nugroho, E. Lidström, B. Iandolo, J. B. Wagner, C. Langhammer, *Nano Lett.* **15**, 3563–3570 (2015).
[4] L. Boon-Brett, J. Bousek, G. Black, P. Moretto, P. Castello, T. Hübert, U. Banach, *Int. J. Hydrogen Energy* **35**, 373–384 (2010).